

EVA Suit R&D for Performance Optimization

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Introduction: Designing a planetary suit is very complex and often requires difficult trade-offs between performance, cost, mass, and system complexity. To verify that new suit designs meet requirements, full prototypes must be built and tested with human subjects. However, numerous design iterations will occur before the hardware meets those requirements. Traditional draw-prototype-test paradigms for R&D are prohibitively expensive with today's shrinking Government budgets.

Personnel at NASA are developing modern simulation techniques which focus on human-centric designs by creating virtual prototype simulations and fully adjustable physical prototypes of suit hardware. During the R&D design phase, these easily modifiable representations of an EVA suit's hard components will allow designers to think creatively and exhaust design possibilities before they build and test working prototypes with human subjects. It allows scientists to comprehensively benchmark current suit capabilities and limitations for existing suit sizes and sizes that do not exist. This is extremely advantageous and enables comprehensive design down-selections to be made early in the design process, enables the use of human performance as design criteria, and enables designs to target specific populations.

Objectives: The primary objective was to develop modern simulation techniques (modeling and reconfigurable prototypes) for evaluating the human performance component of optimal EVA suit concepts.

Methods: This project simulated variations in EVA suit shoulder joint design and subject anthropometry and measured the general changes in mobility due to the modifications. The impacts of these different design changes were simulated and measured in CAD simulation or with human-in-the-loop testing in the Reconfigurable Hard Upper Torso (RHUT). These estimations were compared to human-in-the-loop test data gathered during past suited testing.

Results: Results demonstrated that EVA suit models are feasible design tools for evaluating and optimizing suit performance. Our suit simulation model was found to be beneficial in its ability to visually represent complex motions and volumetric reach zones in three dimensions, giving designers a faster and deeper comprehension of suit component performance vs. human performance.

Suit models were able to adhere to the rigid body contacts and other dynamic constraints that were provided, and behaved in a like manner to the actual suit hardware. The model was able to create movement patterns similar to Human-In-The-Loop (HITL) test data. Although some aspects of the actual human-suit system were

either not modeled or modeled with known inaccuracies, the model at this stage of its development was not inhibited by these limitations.

The RHUT design and pilot test was also successful. The RHUT frame rigidity was more than adequate for any loading incurred during mobility testing. As tested, it was fairly easy to set the orientation and location of the rings to within $\pm 1^\circ$ and ± 0.5 cm of specified values.

The pilot test data for the RHUT showed that for the motions most directly related to the EMU's Optimal Work Envelope (adduction and internal transverse rotation) there was little difference seen between the RHUT and sleeveless EMU conditions.